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Electric Shock: Interpretation of Field Notes

The Effect of Chemically Pure Carbon Monoxide, Illuminating Gas, and Automobile Exhaust Gas upon the Fragility of the Red Blood Cells

Contamination of Food Cooked or Stored in Contact with Nickel-Chromium-Iron Alloys

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THE JOURNAL OF INDUSTRIAL HYGIENE

VOLUME XII OCTOBER, 1930 NUMBER 8

ELECTRIC SHOCK: INTERPRETATION OF FIELD NOTES*

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Toronto, Canada

INFORMATION in connection with cases of electric shock in Canada and the United States has been collected over a period of the last twelve years. In 1928, the interpretation of the information then available, together with details of the report forms and other information pertaining to the Insull Medal and the Canadian Electrical Association Resuscitation Medal, was published in THIS JOURNAL[1] in a report prepared for the Engineering Committee of the Conference on Electric Shock. The present report is based on information available in the medal report files and on information, particularly regarding fatal cases of electric shock, obtained from various large utility and electrical manufacturing companies. The thanks of the author are extended to the National Electric Light Association and the Canadian Electrical Association for their courtesy in allowing information to be taken from their files, and to the executives and field forces of the utility and electrical manufacturing companies for their co-operation in reporting cases.

Reports of approximately 700 cases of electric injuries have been obtained. These have been carefully examined, and 479 cases have been selected which meet the following requirements:

1. A person receives an electric shock, becomes unconscious, and stops breathing. Resuscitation is started, and the patient breathes and lives. 323 cases.

2. A person receives an electric shock, becomes unconscious, and stops breathing. Resuscitation is started but fails to restore breathing, and the patient dies. 156 cases.

The rejected cases come in such groups as: broken neck, extensive burns leading to death, patient did not cease

* Received for publication May 16, 1930.

[1] Recent Experience of the Public Utilities of the United States and Canada in the Use of the Schäfer Prone Pressure Method of Resuscitation in Cases of Electric Shock. THIS JOUR., 1928, *10*, 117.

breathing, no resuscitation performed —the patient dying, insufficient information, and so on. It was felt that by limiting the present investigation to very definite types of cases, those lending themselves to comparison, some definite trends might be disclosed which would confirm laboratory work on animals and open up new leads for future laboratory work.

In many cases of electric shock which occur in the field, the victim becomes unconscious and stops breathing. Electrical workers, generally, have been trained in the prone pressure method of resuscitation, and have been instructed to apply it promptly and to continue it until there are specific evidences of death or until the patient breathes naturally. In cases of apparently similar types of shock, it has been found possible to resuscitate one victim and impossible to resuscitate another. This condition has led to a very extensive investigation into the whole subject of electric shock; and much animal experimentation has resulted in more exact knowledge of the effect of the passage of electric current through a living animal. However, careful and exact information from field cases must be obtained and interpreted in the light of the results of laboratory work before deductions from experimentation and investigation can be of real value in an actual case of electric shock in man.

It is a well-known and acknowledged fact that in some cases of electric shock, even at high potentials and resulting in severe burns, the victim does not cease breathing. These cases, however, are exceptions and will be dealt with only by reference.

Analysis of Data

No attempt has been made to compare the efficacy of resuscitation in all cases of electric shock, but a particular group of cases has been selected which represents the great majority of cases that occur. In various groupings, such as by month, by hour, by potential, and so on, the percentage of successful cases in the entire group has been determined. By comparing the various percentages for, say, the different months of the year, an interpretation may be made as to the variation in severity of shock, if any, between the different months.

TABLE 1.—RECORD OF ACCIDENTS BY YEAR

YEAR	TOTAL CASES	SUCCESSFUL CASES
1918	2	..
1919	2	..
1920	3	2
1921	6	1
1922	17	12
1923	20	15
1924	33	28
1925	52	44
1926	73	56
1927	102	65
1928	98	61
1929	71	39
Total.....	479	323

Comparison by Years

Table 1 shows the year in which the accident occurred. As the medal reports started in 1922 and the personal canvass for reports of fatal cases started in 1927, naturally more information is available for the recent years. There is also a time lag in the reporting of cases; hence complete

records of all cases for 1929 are not yet available.

Comparison by Months

Table 2 shows for each month the total number of cases and the number and percentage of successful cases. As most of the victims of the shocks were public utility employees working outside, one would expect more accidents in the summer months; it will be seen from the table, however, that the percentage of successful cases seems to fall, as the year progresses, until late summer when it rises again. This is more clearly shown in Figure 1. The third degree curve shows the maximum of successful cases on March 1 and the minimum on September 1. An interpretation of this last fact might be that the employees were then wearing less clothing, and owing to hot weather were perspiring. Under these circumstances the electric contact would be better, or, in other words, the resistance at the point of contact between patient and conductor would be less. As the contact resistance is a large part of the total resistance of the victim, the total resistance is greatly reduced. For an equal potential this will result in a greater current passing through the victim. Laboratory results show that with increased current the shock is more severe, all other conditions being equal.

TABLE 2.—RECORD OF ACCIDENTS BY MONTH

MONTH	TOTAL CASES	SUCCESSFUL CASES		VALUES GRADUATED BY THE CURVE $y = 62.521 - 3.169 + 0.728 x^2 + 0.165 x^3$	DESCENDING TREND LINE $y = 63.471 - 2.412 x$	ASCENDING TREND LINE $y = 51.332 + 5.925 x$
		No.	Per Cent.			
Jan.....	16	11	69	72.1	77.9	
Feb.....	22	19	86	75.9	75.5	
March...	26	17	65	75.3	73.1	
April....	28	22	79	74.1	70.7	
May.....	53	36	68	70.5	68.3	
June.....	69	51	74	66.3	65.9	
July.....	68	37	54	62.5	63.5	
Aug.....	67	43	64	60.2	61.1	
Sept.....	45	26	58	60.4		63.2
Oct.....	38	24	63	64.0		69.1
Nov.....	30	23	77	72.1		75.0
Dec.....	17	14	82	85.5		81.0
Total..	479	323	67	...	...	...

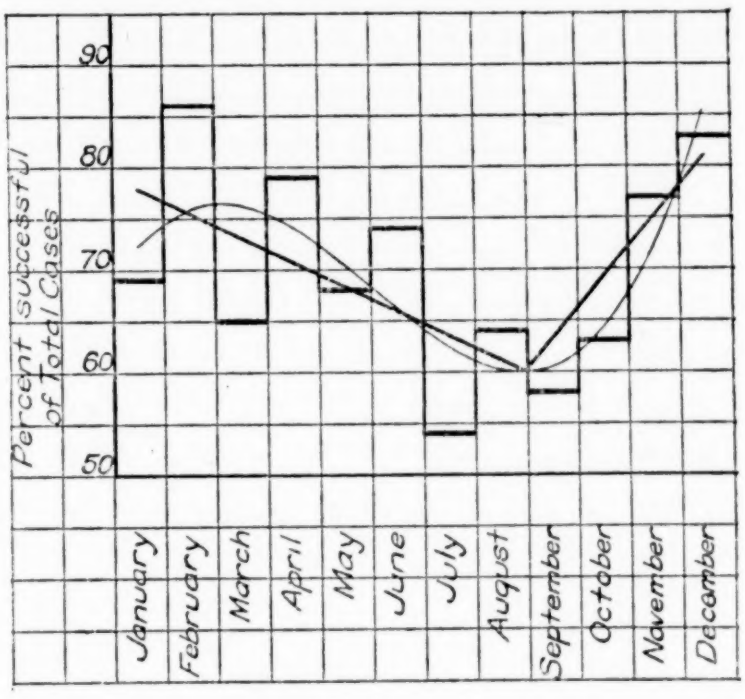

FIG. 1.—Comparison of successful resuscitation cases. The block curve gives the percentage of successful cases by months; the third degree curve, calculated from these values, shows the maximum on March 1 and the minimum on September 1; the two straight lines show the trend. (Although the exactness of mathematical precision was carried out in the development of these curves and lines, the practical value is only to show a trend.)

Comparison by Hours

In Table 3 is given the hour of the day in which the accident occurred. It will be noted that for the normal

working day—*i.e.*, from 8 A.M. to 5 P.M.—the percentage of successful cases increases as the day progresses, with the break for noon hour, and reaches a maximum between 1 P.M. and 2 P.M., and then falls during the afternoon. Figure 2 shows the percentage of successful cases by hours. The working day was chosen because

TABLE 3.—RECORD OF ACCIDENTS BY HOUR

HOUR	TOTAL CASES	SUCCESSFUL CASES	
		No.	Per Cent.
5– 6 a.m.	1	...	...
6– 7	1	1	100
7– 8	13	10	77
8– 9	25	14	56
9–10	53	30	57
10–11	49	34	69
11–12 m.	60	44	73
12– 1 p.m.	12	7	58
1– 2	34	26	77
2– 3	61	44	72
3– 4	68	43	63
4– 5	36	23	64
5– 6	25	19	76
6– 7	12	8	67
7– 8	10	6	60
8– 9	7	6	86
9–10	4	3	75
No time	8	5	63
Total....	479	323	67

the work and supervision are the same during these hours. At other times varying conditions prevail. A comparison of the percentage successful between 5 P.M. and 6 P.M. with that between 2 P.M. and 3 P.M. would obviously be incorrect because, to mention only one variable, different shifts would probably be working. It will be seen that the curve for the morning is the reverse of the curve for the afternoon. The falling of the percentage of successful cases during the afternoon may be interpreted as the effect of fatigue on the severity of the shock or on the success of resuscita-

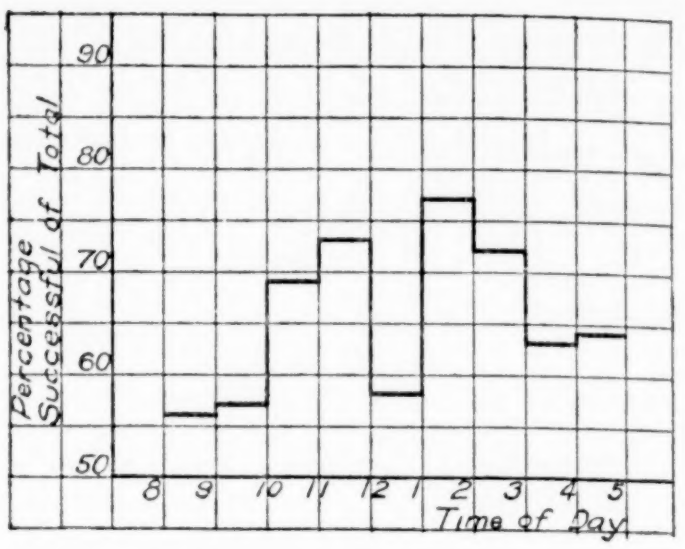

FIG. 2.—Comparison of successful resuscitation cases by hours during the working day.

tion. No such interpretation would, however, apply to the morning. It would seem that laboratory work to clear up this matter is indicated.

Comparison by Potential of Circuit

In Table 4 is shown the potential of the circuit involved in the accidents,

TABLE 4.—RECORD OF ACCIDENTS BY POTENTIAL OF CIRCUIT INVOLVED

VOLTAGE	TOTAL CASES	SUCCESSFUL CASES	
		No.	Per Cent.
0– 749.....	65	41	63
750– 4,999.....	212	138	65
5,000–39,999.....	167	116	69
40,000 and over.....	26	23	88
Lightning.....	2	2	100
Induced current.....	4	2	50
No voltage given.....	3	1	33
Total.....	479	323	67

and the percentage of successful cases at each potential. The divisions selected show: (1) the potential of the circuits commonly used in houses and manufacturing firms; (2) the primary distribution voltage in towns and cities; (3) transmission voltages of a secondary character; and (4) voltage for long distance transmission. The first is handled by laymen as well as by trained electrical workers, and the contact with it is liable to be solid and hence of low resistance. The second is usually handled by trained electrical workers using insulating rubber gloves and other protection, and the contact is accidental and poor. In the last two cases, it is handled only by trained electrical workers with special appliances, and contacts are accidental; frequently there is no direct contact between conductor and victim but contact through an arc.

It will be seen that as the potential rises, the percentage of successful cases also rises. At least one cause for this is the probability that the contact in the higher potentials is poor and of brief duration.

Comparison by Duration of Contact

In field cases, it is impossible to learn the exact duration of the contact. It is possible, however, to get a gauge of this. In the report form the question was asked: "How was victim cleared from the circuit?" Many reported, "Fell clear;" others, "Pulled clear;" and still others, "Switch was opened." In the case of a victim falling clear, the duration is very short; if the victim has to be pulled clear or if the switch has to be opened, there is a contact of appreciable time.

Table 5 shows the percentage of successful cases in which the victim "fell clear;" all other cases are grouped under "pulled clear." It is noticeable that a higher percentage of successful cases is in the group "fell clear." This would tend to suggest that the duration of contact is a gauge of the severity of the shock and would support laboratory work along this line. This is very noticeable in those cases with potentials of 0 to 750 volts, and in those with potentials of 40,000 volts and over; in the first instance, the contact being usually good and in the second, the current passing through the victim being high.

TABLE 5.—RECORD OF ACCIDENTS BY METHOD OF CLEARING PATIENT FROM CIRCUIT

METHOD OF CLEARING	TOTAL CASES	SUCCESSFUL CASES	
		No.	Per Cent.
Fell clear	282	198	70
Pulled clear[1]	197	125	63
Total	479	323	67

[1] All those cleared by other means than falling clear.

Comparison by Time between Shock and Application of Resuscitation

It is difficult, if not impossible, to obtain the exact time that elapses between the shock and the first application of resuscitation. This is primarily due to the fact that those present are excited, and their first thoughts are for the relief of the victim. An analysis has, however, placed the cases in two groups: those in which a very short time elapsed

between the shock and the application of resuscitation, three minutes or less; and those in which there was a longer lapse of time, four minutes or more.

In Table 6 is shown the percentage of successful cases in these two groups. From this it is quite apparent that more success is obtained by the prompt application of resuscitation. This is noticeable in all groupings both as to voltage and as to duration of contact. Laboratory work on animals also points to this conclusion.

TABLE 6.—RECORD OF ACCIDENTS BY TIME ELAPSED BETWEEN ACCIDENT AND COMMENCEMENT OF RESUSCITATION

MINUTES ELAPSED	TOTAL CASES	SUCCESSFUL CASES	
		No.	Per Cent.
0–3	361	254	70
4 and over	118	69	58
Total	479	323	67

Path of the Current

A careful examination of the cases was made with a view to finding whether any information was available as to the path of the current in shock cases. Since most of the cases were those of workmen, they would be liable to contact from hands or arms, and since in many instances they were standing on ground or with their feet in contact with ground wires, the path of the current would traverse the trunk. On examination, it was found that the path of current was from head to feet; hands to feet; arms to legs; or hand to hand. In each case the path was practically the same. No particular difference in percentage of successful cases for the various points of contact could be obtained. Owing to the very routine of the work carried out by the men, the path of current is likely to be the same.

Individual Cases

In carrying out the analysis, many interesting individual cases were noted. One is particularly impressed by the careful and extensive training of public utility employees in the prone pressure method of resuscitation, first put forward by Sir Edward Sharpey Schäfer, and also by the promptness with which it is applied. In over 75 per cent. of the cases under consideration, resuscitation was commenced within three minutes of the accident. When one considers that during this time the victim had to be cleared from the pole or other structure and be placed in position, the results of training and instruction are quite easily seen.

In some of the cases under review, the injuries after the effect of shock had passed off, were very slight. In others, the injuries were severe: such as amputation of leg and arm on account of burns, excision of the entire top of the skull on account of necrosed bone, and development of cataract. In no case of resuscitation, was there any permanent paralysis unless gross destruction of tissue had taken place; and no evidence of paralysis of the lower limbs was indicated in the fatal cases.

It is seldom possible to obtain a clear-cut statement from a victim of electric shock as to sensations imme-

diately after the accident. The following statement from a line foreman is, however, the clearest that has come to the author's attention. This case was not considered in the above analysis, for resuscitation was neither indicated nor performed.

In reference to my accident of Feb. 9, 1929, when accidentally coming in contact with 22,000 volt line at front of substation: I had a ladder placed against the substation wall which reached a height of approximately forty feet and upon climbing to the top of the ladder, I grasped an anchor bolt that was secured in the cement wall with my left hand (I was wearing a pair of leather gloves), and I passed my right hand over to the line upon which I had thought dead and was intending to remove a tap.

When the back of my right hand came to within a half or three-quarters of an inch on the conductor, six or seven tiny blue waves, threadlike streaks of flame, suddenly leaped to my second knuckle of ring finger on right hand. Immediately my head seemed to enlarge and burst with pain, and I heard the most terrific noises in my head and ears, as if I were inside a most powerful generator and seemed to feel the pulsations with its powerful hum; while at the same time, my body, legs, and feet seemed to shrink to nothing, until I felt I could stand on a ten cent piece. Both hands, at the same time, had a stinging, burning sensation. I can't begin to tell you how many seconds this lasted, but it seemed to me a terribly long time.

My senses were partially numb but I was conscious and felt that I was in the grip of some powerful monster. My efforts to move my right hand or arm were futile against its magnetic strength. Even my eyes were fixed in a stare as I watched those hairlike streaks pouring into my finger, and at no time were they any larger than half an inch in diameter.

I think I owe my life to getting clear of it with my left hand which was holding the anchor bolt, and I found it one of the hardest tests of concentration of will power in trying to use the muscles of my left hand. Even my sense of feeling was gone, and I could not shift my eyes from staring at those blue streaks.

I failed in my first attempt to use my muscles in my left hand; in fact I felt like a wooden man. I had no power of any muscles, and then some superhuman will power seemed to concentrate on my left hand, and I had the sensation of feeling my finger slowly dragging off that bolt; and pain increased as I was losing contact. It was my first glimpse of my left hand as I saw it leave the wall. I had no sense of balance left nor any fear that I might fall, and was glad to get away from that awful torture. It is torture and if electrocution has that feeling, then God help the criminals. Anyway, I felt that I had won out, when I took a left turn and plunged toward the ground. The snow below looked very faint, and I felt as if I were in semidarkness as I could see the foot of the red ladder below, and as I gained speed it grew darker. With my ears ringing, my head swimming, and my brain trying to fight those terrific noises, I tried to keep my senses or rather partial senses. It seemed so easy to pass out, and then as I was about halfway down, the noise increased; and then with a bang as if my head had exploded, I was in inky darkness.

Not until then, did I feel that I was done for, but the next instant my eyes flew open, and I felt myself being propelled upward. I was looking at the white snow, and my senses were partially awake, and I realized that I had fallen flat on my stomach; my arms and legs were fully extended, and as I met the snow the second time, my head cleared of all those hellish sounds; perhaps I had bounced about a foot, as there were about nine inches of snow.

My senses then cleared immediately; my first act was to spit out a mouthful of snow, rub the snow out of my eyes, put my hands forward, and stand up. I didn't stop to examine my hands, although they were stinging terribly, and I knew they were burned. I suddenly thought of getting oil to put on them and started round the building to go upstairs, such an act as I was always taught not to allow anyone to do, but it did not occur to me then. I had my mind fixed on getting to that oil. I tucked my hands under my armpits and was on my

way when I was met by my fellow worker who stepped in front of me and asked me what was the matter. For some unknown reason I felt very antagonistic towards him, felt as if he were going to try and stop me; so simply said, "I made a mistake," put my shoulder against him and started on again.

I took a few steps more, when my workman confronted me again with, "Where are you going?" I said, "Get out of my way, get my cap," and went on up the twelve or fourteen steps to the main floor. My heart was pounding, but I felt pretty fair, and on the landing at the top I met my brother. I asked him to get the oil. Didn't offer any explanation, but he seemed to know by my face that I needed it. I then sat down on a chair in the operator's office as I felt all in and began to battle with my senses again. It was useless and I didn't have enough sense to ask for help—just floated away. My next sensation was of being dragged along the floor, as they were preparing to apply respiration, but I managed to say I didn't need any help.

I was kept lying down and they bathed my hands in oil and it did relieve the pain at once. The doctor examined me then, and they proceeded to remove me to an ambulance. While in the ambulance I had a great fight to keep from passing out. It seemed so easy to float away, but I kept bumping my head on the stretcher, and each bump seemed to clear my head. When I arrived at the hospital, I was given a drink of whiskey, and my attention was again on my burns which consisted of one finger on my right hand burned to the bone and two holes in the muscle of my left thumb where I had made a partial ground connection.

P.S. Forgot to mention that after coming into the substation, I was very cold, even though I had a lot of extra clothing and blankets, and it took about two hours to get warm.

Any number of interesting cases of resuscitation might be described in order to bring out various facts. That it has been possible, by hours of continuous effort, to resuscitate an apparently lifeless victim of electric shock has been referred to by many authors; and at least one explanation has been put forward as a result of laboratory work. There follows a brief description of the longest case of resuscitation after electric shock that has come to the author's attention.

On May 22, 1927, at 2 P.M. a young lineman in a town in Ontario received a shock of 22,000 volts from head to hands and legs. He fell back into his life belt, unconscious and not breathing. He was lowered to the ground by fellow employees and resuscitation commenced at once. A doctor was called, and the patient was removed to the hospital in an ambulance, resuscitation being carried out during transportation. Boards were placed over a hospital bed and resuscitation continued. At 2:40 P.M. long distance telephone communication between the attending doctor and consultant in Toronto was established and maintained as required. Sufficient trained employees remained in the hospital in order to relieve each other and thus carry out resuscitation efficiently without fatigue. Attempts were made from time to time to stop resuscitation, but the patient would not breathe voluntarily. Between 7 and 8 P.M. the patient became cyanosed, but this cleared up on change of operators. At 10 P.M. the patient breathed of his own volition, and manual resuscitation was discontinued. Employees were left in the hospital during the night to apply resuscitation if necessary. The patient stopped breathing once, but recommenced before resuscitation could be applied. By continued application of efficient prone pressure resuscitation, success was reached after eight hours' effort.

Conclusions

From a consideration of the cases under review, the following conclusions may be reached:

1. The severity of the shock increases or the success of resuscitation decreases as the year progresses, until late summer when the severity of shock decreases or the success of resuscitation increases.

2. The severity of the shock decreases or the success of resuscitation increases as the day progresses (with a break for noon hour), reaching a peak at 1 to 2 P.M. when the severity of shock increases or the success of resuscitation decreases.

3. The severity of the shock decreases or the success of resuscitation increases as the potential of the circuit involved increases.

4. The severity of the shock is less or the success of resuscitation is more, in cases where the victim fell clear of contact than in those in which the victim was cleared by other means.

5. The success of resuscitation is more in cases where the application of resuscitation is carried out in three minutes or less after the shock, than in those in which it is carried out in four minutes or more.

6. No information is available as to the severity of the shock or the success of resuscitation for various paths of current through the victim, since the nature of the work makes the paths of current the same.

Interpretation of these conclusions leads one to believe:

1. That the severity of the shock is increased by the reduction of contact resistance.

2. That laboratory work is indicated to explain the apparent difference of severity of shock between different hours of the day.

3. That the severity of the shock is increased by the increase in the duration of contact.

4. That the success of resuscitation is increased by the prompt application of resuscitation.

5. That public utility employees have been well trained in the prone pressure method of resuscitation.

6. That success in resuscitation from electric shock may result after many hours' work on an apparently lifeless victim.

The author wishes to express his thanks to Miss M. B. Woods, Secretary of the Insull Medal Awards Subcommittee, for the careful preparation of information from the files; to Mr. Hugh Wolfenden, Consulting Actuary, for checking the tables and preparing the curves; and to many who made possible the preparation of the paper.

THE EFFECT OF CHEMICALLY PURE CARBON MONOXIDE, ILLUMINATING GAS, AND AUTOMOBILE EXHAUST GAS UPON THE FRAGILITY OF THE RED BLOOD CELLS*

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TO investigators interested in the subject of carbon monoxide poisoning, the question of the relative toxicity of carbon monoxide in its pure state and of carbon monoxide as found in such substances as illuminating gas and the exhaust gas from automobiles is one of considerable importance.

Henderson and Haggard,[1] who conducted a series of interesting experiments along these lines, have shown that illuminating gas, even in relatively low concentration, will kill a fragment of chick brain, though the latter has been shown to grow very satisfactorily in an atmosphere of pure carbon monoxide. They have also shown that exposure to illuminating gas will kill insects which have no hemoglobin and which are known to be immune to carbon monoxide poisoning. Further experiments by the same investigators[2] have shown that when animals are exposed to illuminating gas or to exhaust gas from a car using coal distillate, the carbon monoxide contained in these gases appears to be far more toxic to them than is the same concentration of pure carbon monoxide. Indeed, in the presence of these gases, if their blood becomes, respectively, 70 per cent. and 60 per cent. saturated with carbon monoxide, the animals invariably die, while even a blood saturation of 80 per cent. was survived by the same animals when chemically pure carbon monoxide was used. Henderson and Haggard consider that while carbon monoxide is undoubtedly the chief toxic element in these gas mixtures, as much as 25 per cent. of their toxicity is probably due to other substances.

Rudolf Hofer[3] conducted a careful

*Received for publication May 9, 1930.

[1] Haggard, H. W., and Henderson, Y.: The Treatment of Carbon Monoxid Poisoning. Jour. Am. Med. Assn., 1921, *77*, 1065.

[2] The Comparative Toxicity of Pure Carbon Monoxide, Illuminating Gas, Exhaust Gas from Gasoline, Exhaust Gas from Coal Distillate and Gasoline Vapor. Report of New York State Bridge and Tunnel Commission, Appendix No. 4, p. 180. Albany, J. B. Lyon Co., 1921.

[3] Hofer, R.: Über die Wirkung von Gasgemischen. Arch. f. exper. Path. u. Pharmakol., 1926, *111*, 183.

experimental study for the purpose of determining the toxic action of mixed gases, as compared with the toxicities of each individual gas. His findings are extremely pertinent to the present discussion, and may be briefly summarized as follows:

1. Combination tests with carbon monoxide and hydrogen sulphide show that hydrogen sulphide in concentrations of 0.04 vol. % and carbon monoxide in concentrations of 0.5 vol. %, which do not have a fatal effect when inhaled for a period of 10 minutes, are found to be deadly when inhaled simultaneously for the same length of time. When the experimental animal was exposed for a longer period than this, one-half the fatal concentration of each gas was sufficient to cause death when given in combination.

2. The combination tests with carbon monoxide and hydrocyanic acid show that even a combination of 0.1 vol. % carbon monoxide and 0.0018 vol. % hydrocyanic acid induces severe paralysis. The same degree of action is not achieved in separate inhalations until the cat has inhaled 0.25–0.3 vol. % carbon monoxide (*i.e.*, a concentration two and one-half to three times as great) and 0.0045 vol. % hydrocyanic acid (*i.e.*, a concentration more than twice the above).

It would seem from these experiments that a mixture of carbon monoxide with one or more toxic gases is more toxic than is the sum of the toxicities of the individual gases.

Since large numbers of workers are exposed to illuminating gas and exhaust gas rather than to pure carbon monoxide, it becomes a matter of more than theoretical interest to arrive at a proper understanding of the precise differences in their relative toxicities, in terms of physiologic and biochemical reactions upon those exposed. The present series of *in vitro* experiments was undertaken with a view to acquiring information upon only one small phase of the question—namely, the relative power of chemically pure carbon monoxide, illuminating gas, and exhaust gas to hemolyze the red blood cells. To this end, normal blood was exposed to all three substances to the point of saturation, and the fragility of the red blood cells was determined as described in the following report.

Experimental Study

1. Fragility of Untreated Red Blood Cells

Procedure.—Each 15 c.c. of blood was collected in a tube containing the residue of 1 c.c. of sodium citrate (8 per cent. solution). Then 0.05 c.c. of whole blood was pipetted into 2 c.c. of sodium chloride solution (concentrations ranging from 0.25 to 0.6 per cent.) and mixed carefully. Examination for hemolysis was made after two hours and after twenty-four hours. Duplicate determinations were done on each blood.

Results.—The findings on three bloods (Table 1) show that complete hemolysis occurred in sodium chloride concentrations between 0.25 and 0.33 per cent., and partial hemolysis in concentrations between 0.34 and 0.43 per cent.

TABLE 1.—DEGREE OF HEMOLYSIS: UNTREATED RED BLOOD CELLS

BLOOD SAMPLE	COMPLETE HEMOLYSIS		PARTIAL HEMOLYSIS		NO HEMOLYSIS	
	% Concn. NaCl	No. of Tests	% Concn. NaCl	No. of Tests	% Concn. NaCl	No. of Tests
1	0.25–0.33	9	0.34–0.43	10	0.44–0.60	17
2	0.25–0.33	9	0.34–0.43	10	0.44–0.60	17
3	0.25–0.32	8	0.33–0.43	11	0.44–0.60	17

2. Fragility of Aerated Red Blood Cells

Procedure.—Air which had been washed through sulphuric acid was bubbled through the whole blood for fifteen to eighteen minutes at a rate which just permitted the bubbles to be counted and which did not give rise to too much frothing. The remaining steps in the technic were the same as those for untreated blood.

Results.—Complete hemolysis occurred in sodium chloride concentrations between 0.25 and 0.32 per cent.; partial hemolysis in concentrations between 0.33 and 0.45 per cent. (Table 2). These findings are practically the same as those for untreated blood. There is, however, a tendency to a somewhat greater stability in aerated cells.

TABLE 2.—DEGREE OF HEMOLYSIS: AERATED BLOOD

BLOOD SAMPLE	COMPLETE HEMOLYSIS		PARTIAL HEMOLYSIS		NO HEMOLYSIS	
	% Concn. NaCl	No. of Tests	% Concn. NaCl	No. of Tests	% Concn. NaCl	No. of Tests
1	0.25–0.32	8	0.33–0.45	13	0.46–0.60	15
2	0.25–0.32	8	0.33–0.40	8	0.41–0.60	20
3	0.25–0.32	8	0.33–0.43	11	0.44–0.60	17
4	0.25–0.31	7	0.32–0.41	10	0.42–0.60	19

3. Effect of Pure Carbon Monoxide on Fragility of Red Blood Cells

Procedure.—Carbon monoxide was generated by passing pure sulphuric acid (specific gravity 1.84) into pure formic acid. The gas was led from the generating flask through soda lime into the blood at the same rate as was used for ordinary aeration in experiment 2. The usual procedure was then followed.

Results.—There was complete hemolysis in sodium chloride concentrations between 0.25 and 0.33 per cent.; partial hemolysis in concentrations between 0.34 and 0.45 per cent. (Table 3). The degree of hemolysis is just slightly greater than in untreated blood.

TABLE 3.—DEGREE OF HEMOLYSIS: BLOOD TREATED WITH CARBON MONOXIDE

BLOOD SAMPLE	COMPLETE HEMOLYSIS		PARTIAL HEMOLYSIS		NO HEMOLYSIS	
	% Concn. NaCl	No. of Tests	% Concn. NaCl	No. of Tests	% Concn. NaCl	No. of Tests
1	0.25–0.32	8	0.33–0.45	13	0.46–0.60	15
2	0.25–0.33	9	0.34–0.42	9	0.43–0.60	18
3	0.25–0.33	9	0.34–0.43	10	0.44–0.60	17

4. Effect of Illuminating Gas on Fragility of Red Blood Cells

Procedure.—The gas passed from the jet through calcium chloride and then into whole blood at a rate approximating as nearly as possible that used for ordinary aeration. The usual procedure was then followed.

Results.—Complete hemolysis occurred in concentrations ranging from 0.25 to 0.37 per cent.; partial hemolysis in concentrations from 0.37 to 0.48 per cent. (Table 4). The degree of hemolysis shows a marked increase over that produced by carbon monoxide.

TABLE 4.—DEGREE OF HEMOLYSIS: BLOOD TREATED WITH ILLUMINATING GAS

BLOOD SAMPLE	COMPLETE HEMOLYSIS		PARTIAL HEMOLYSIS		NO HEMOLYSIS	
	% Concn. NaCl	No. of Tests	% Concn. NaCl	No. of Tests	% Concn. NaCl	No. of Tests
1	0.25–0.36	12	0.37–0.45	9	0.46–0.60	15
2	0.25–0.36	12	0.37–0.48	12	0.49–0.60	12
3	0.25–0.37	13	0.38–0.48	11	0.49–0.60	12

5. Effect of Automobile Exhaust Gas on Fragility of Red Blood Cells

Procedure.—The exhaust gas was collected in special sampling flasks. It was then led through calcium chloride into the blood, at the rate used previously. Other steps in the procedure were the same as in the foregoing experiments.

Results.—There was complete hemolysis in sodium chloride concentrations ranging from 0.25 to 0.36 per cent.; partial hemolysis occurred in concentrations between 0.37 and 0.47 per cent. (Table 5). The effect of automobile exhaust gas on the fragility of the red blood cells is, therefore, somewhat less than that of illuminating gas.

TABLE 5.—DEGREE OF HEMOLYSIS: BLOOD TREATED WITH AUTOMOBILE EXHAUST GAS

BLOOD SAMPLE	COMPLETE HEMOLYSIS		PARTIAL HEMOLYSIS		NO HEMOLYSIS	
	% Concn. NaCl	No. of Tests	% Concn. NaCl	No. of Tests	% Concn. NaCl	No. of Tests
1	0.25–0.35	11	0.36–0.44	9	0.45–0.60	16
2	0.25–0.36	12	0.37–0.46	10	0.47–0.60	14
3	0.25–0.36	12	0.37–0.47	11	0.48–0.60	13

6. Effect of the Various Gases on Hydrogen Ion Concentration

Procedure.—Sodium chloride solution (0.9 per cent.) was adjusted to a hydrogen ion concentration of 7.4. Samples of this solution were treated with air, carbon monoxide, illuminating gas, and automobile exhaust gas, in accordance with the procedure used for the blood. The hydrogen ion concentration was then determined. These determinations were repeated, using a buffer solution (M/15 $Na_2HPO_4.2H_2O$:M/15 KH_2PO_4 in the proportions 80.4:9.6), the hydrogen ion concentration of which was 7.35.

Results.—All the sodium chloride samples (hydrogen ion concentration 7.4) lost their alkalinity very rapidly. With the buffer solution, the effect was not so marked. Carbon monoxide and illuminating gas lowered the hydrogen ion concentration to 7.3. The air treated sample and the exhaust gas sample had hydrogen ion concentrations of 7.2 and 7, respectively.

The hemolysis produced in experiments 1 to 5 cannot be due to any change in hydrogen ion concentration, since the buffering action of the blood is greater than that of the phosphate solution as shown in experiment 6.

Summary

Experiments are reported which were undertaken for the purpose of studying the effect of pure carbon monoxide, illuminating gas, and automobile exhaust gas on the fragility of red blood cells. A comparison of the hemolysis observed under the different conditions of exposure is given in Table 6.

When normal blood was exposed to pure carbon monoxide gas under laboratory conditions, there was no increase in the fragility of the red blood cells.

Normal blood exposed to both illuminating gas and automobile exhaust gas, under the same laboratory conditions, showed a tendency to a somewhat increased hemolysis of the red cells. The increase in hemolysis due to automobile exhaust gas is slightly less than that produced by illuminating gas.

The hemolyzing effect of these gases would seem therefore to be due to the presence of other toxic constituents rather than to their carbon monoxide content.

TABLE 6.—COMPARISON OF HEMOLYSIS OF RED BLOOD CELLS UNDER DIFFERENT CONDITIONS OF EXPOSURE

TREATMENT	NO. OF TESTS	PERCENTAGE SHOWING			AVERAGE POINT[1] OF	
		Complete Hemolysis	Partial Hemolysis	No Hemolysis	Complete Hemolysis	Beginning Hemolysis
None	108	24.1	28.7	47.2	0.33	0.43
Aeration	144	21.5	29.2	49.3	0.32	0.42
Carbon monoxide	108	24.1	29.6	46.3	0.33	0.43
Illuminating gas	108	34.3	29.6	36.1	0.36	0.47
Automobile exhaust gas	108	32.4	27.8	39.8	0.36	0.46

[1] Percentage concentration of sodium chloride.

The hemolysis produced by the several treatments outlined was not due to a change in the hydrogen ion concentration of the blood.

CONTAMINATION OF FOOD COOKED OR STORED IN CONTACT WITH NICKEL-CHROMIUM-IRON ALLOYS*

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FROM the time of Brearley's discovery of the corrosion protective action of chromium in steel (1), industrial development of these alloys and their application to many important uses have progressively increased. Not the least of these is the recent development of nickel-chromium-iron alloys and their utilization for culinary purposes. The corrosion resistant nature of nickel has long been known and the possible use of pure nickel cooking utensils has been subjected to a searching examination within recent years (2), with results that established the very low intake that could occur and the general harmlessness of these small amounts. The nickel-steel alloys are far more resistant to corrosion than pure nickel itself and would seem ideally suitable for food containers of all sorts. It is necessary, however, from a public health point of view to test these materials in terms of practical usage.

These newer nickel-chromium-iron alloys have the great advantages of noncorrosive properties, of light weight, and of remaining clean and bright under conditions which quickly affect the appearance of other materials. These steels are composed of iron, chromium, and nickel in varying proportions and show a remarkable resistance to corrosion under extreme conditions. Their use for the manufacture of culinary utensils is a logical step and has given impetus to the present investigation concerning their hygienic fitness for this purpose.

Plan of Investigation

The steels that were examined in this laboratory were subjected to conditions which duplicated as nearly as possible the household preparation and storage of food. In order to secure the greatest accuracy, the strip tests were made with accurately weighed and measured squares of metal of uniform surface. Other tests were made with cooking utensils in which the results of actual usage could be observed. The chief dependence, however, was placed upon the analytic data.

The hygienic evaluation of a metal to which foods must be exposed in the course of their preparation involves not only such obvious factors as the length of time the food is exposed to the metal and the temperature at which this occurs, but also other factors such as the hydrogen ion concentration or acidity of the food mixture, salt concentration, dissolved oxygen, and, to some extent, the nature of the food. It would be expected that the degree of contamination would be more or less

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proportional to the degree of acidity. That this is not strictly so in the case of these particular alloys is apparent from the data which follow.

The three alloys investigated each contained chromium, nickel, and iron, the proportion only being varied. One of the alloys contained, in addition, a small amount of molybdenum, which has been found to make the metal more resistant to attack of certain sulphur compounds. The approximate composition of these three alloys is as follows:

	QB %	*QA* %	*A* %
Iron	67	65.3	74
Chromium	18	17.0	18
Nickel	15	14.0	8
Molybdenum	0	3.7	0

It will be observed that all three alloys are quite similar in their chromium content. Alloy A, which is being produced commercially under several trade names, has been manufactured into culinary utensils for some time.

Strips of these metals measuring in general 85 mm. by 135 mm., and 0.02 mm. thick, were polished and bent so that two could be arranged in each beaker in which the food materials were cooked. Each strip was accurately weighed, its area exposed to both liquid and air measured, the length of the line of contact noted, and the temperature and time of contact determined. After cooking, the strips were carefully washed free from adhering food materials and were weighed. The washings were added to the contents of the beakers, evaporated to dryness, charred, ashed, and analyzed for chromium, iron, nickel, and molybdenum. The foods before cooking had been previously analyzed for traces of these metals, and by deducting the latter amount from the former, the amount dissolved from the strips was obtained.

In determining the weight losses of the strips, extreme care was necessary in order to obtain significant figures. Owing to the corrosion resistant nature of the alloy and, furthermore, to the fact that the time of contact during ordinary cooking (one hour) is not particularly long, the weight loss is extremely small. There is also another factor to be considered—the formation of a film of tarnish which may affect the weight of the strip in another sense, causing in fact a weight gain.

Tarnish is of importance principally in evaluating the aesthetic advantage of culinary utensils. It does not indicate that the metal has reacted with the food and has contaminated it necessarily. In fact, it may imply quite the opposite from the latter. *As a test for contamination of this type, it is unreliable.*

Owing to the fact that the weight of the metal was considerable as compared with the loss sustained, the weighings were made with a counterpoise of the same metal and of practically the same weight; thus errors due to moisture absorption, etc., were eliminated. In order to attain greater accuracy and because of the minute differences in weight, the weighings were made on a balance accurate to 0.05 mg. The tarnish formed may be classified as of two kinds—superficial and permanent. The superficial tarnish is that which is removable by very gently rubbing the surface with soapy water, either by hand or with soft gauze. The tarnish remaining after

this treatment is more or less closely adherent and requires the use of abrasives for removal. Both degrees of tarnish were determined in terms of an arbitrary scale, ranging from 1 (plainly apparent) to 4 (barely perceptible).

That there was no relation between the change in weight of the metal strip and the amount of metal picked up by the food was apparent when the deposition of some more noble metal present in the food. It was usually most noticeable just at the juncture of contact with the liquid, indicating a possible oxidative effect.

It might be mentioned that in the case of these alloys, tarnish consisted in a barely perceptible film which often required careful illumination to become visible. The weight losses were small,

TABLE 1.—WEIGHT CHANGES AND FILM FORMATION UNDER NORMAL COOKING CONDITIONS

(Total surface in contact with food is 2.5 sq. dm., surface above liquid is 1.5 sq. dm., and line of contact is 53 cm. There are 250 c.c. of food material.)

FOOD	ALLOY QB Fe = 67%, Cr = 18%, Ni = 15%			ALLOY QA Fe = 65.3%, Cr = 17%, Ni = 14%, Mo = 3.7%			ALLOY A Fe = 74%, Cr = 18%, Ni = 8%		
	Rinsed	Washed	Film	Rinsed	Washed	Film	Rinsed	Washed	Film
	mg.	*mg.*		*mg.*	*mg.*		*mg.*	*mg.*	
Apple 1	−1.4	−1.9	4	−1.2	−2.0	4	...	−1.8	4
Apple 2	...	...	4	...	...	4	...	...	4
Chicken	...	−1.0	1	...	−0.3	1	...	−0.6	1
Gooseberries	+0.2	−1.2	4	+0.1	−0.6	4	−0.2	−0.8	4
Rice	−0.8	−2.1	4	−0.6	−0.9	4	−0.8	−1.3	4
Rice (stored)	+0.3	−0.3	4	+0.5	−0.6	4	+0.4	−0.3	4
Potatoes	0.0	−0.2	3	−0.8	−1.2	3	−0.7	−0.8	3
Flounder	+0.4	−1.0	1	+0.5	−0.7	2	+0.6	−0.2	1
Cauliflower	+0.1	−1.1	2	+0.1	−0.9	2	+0.4	−1.3	1
Corn	...	−1.0	4	...	−0.6	4	...	−0.8	4
Custard	−2.2	−1.6	1	+1.6	−0.5	1	+1.1	−0.4	1

latter was submitted to quantitative analysis for the metals involved. The analysis bore no relation to the change in weight. Instead of a weight loss there was occasionally a weight *gain* on rinsed strips only. This was due either to surface oxidation, sulphide formation, or to the formation of an insoluble compound with some constituent of the food, or, possibly, to amounting, in many cases, to only a fraction of a milligram for a 50 gm. strip of metal. Tarnish was not directly proportional to acidity.

The weight changes and the degree of film formation in these metals are shown in Table 1. Table 2 shows the weight changes per 4 square decimeters per hour of contact at boiling point (that is, in terms of the amount

of metal exposed in an ordinary stewpan). This represents about the average surface of metal exposed to food cooked under ordinary domestic conditions. According to these figures, no significant correlation, although the weight loss is somewhat greater for hydrogen ion concentrations below 6.1 than for concentrations above this point.

TABLE 2.—WEIGHT CHANGE PER 4 SQUARE DECIMETERS PER HOUR OF CONTACT AT BOILING POINT

FOOD	ALLOY QB		ALLOY QA		ALLOY A	
	Rinsed	Washed	Rinsed	Washed	Rinsed	Washed
	mg.	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*
Apple 1	−2.5	−3.6	−2.4	−3.8	...	−3.5
Apple 2	...	...	...	...	...	...
Chicken	...	−1.6	...	−0.4	...	−0.9
Gooseberries	+0.5	−2.4	+0.2	−1.2	−0.5	−1.5
Rice	−0.5	−1.3	−0.4	−0.6	−0.6	−0.8
Rice (stored)	0.0	0.0	0.0	0.0	0.0	0.0
Potatoes	0.0	−0.6	−1.6	−1.9	−1.7	−1.9
Flounder	+2.8	−6.4	+3.2	−4.8	+4.0	−2.4
Cauliflower	+0.4	−3.4	+0.4	−2.8	+1.4	−4.2
Corn	...	−9.6	...	−6.0	...	−7.2
Custard	+1.7	−1.3	+1.3	−0.4	+0.9	−0.3

TABLE 3.—EFFECT OF VARIATION IN HYDROGEN ION CONCENTRATION UPON WEIGHT CHANGES

P_H OF FOOD	WASHED WEIGHT LOSS PER SQ. DM.		
	Alloy QB	Alloy QA	Alloy A
	mg.	*mg.*	*mg.*
3.0	0.6	0.4	0.4
3.3	0.9	0.9	0.9
6.0	1.6	1.2	0.6
6.1	0.9	0.7	1.0
6.4	0.4	0.0	0.0
6.4	0.0	0.1	0.2
6.6	0.02	0.7	0.5

there is no marked difference between the various alloys. The weight losses of the three alloys compared with the variation in hydrogen ion concentration of the various foods is shown in Table 3. As indicated above, there is

The point of greatest importance from an hygienic point of view is the quality rather than the quantity of material that contaminates the food. In all cases, therefore, the foods were carefully analyzed after they had been in contact with the metal. These analyses showed that the resistance of the alloy to corrosion is very high, for only a trace of the total metal dissolved could be found in the food and this trace consisted chiefly of iron. The analytic determinations as compared with the strip weight determinations therefore constitute a valuable control, for they not only show accurately the degree to which the metal dissolves, but also show the important fact that the metal which goes into solution from these alloys is principally iron.

The analytic procedure adopted was

as follows: The ash from the completely ashed food was dissolved in hydrochloric acid and water, and was made up to a given volume. Portions of this solution were separately analyzed for iron, chromium, and nickel, and in several cases for molybdenum. These constituents were determined colorimetrically—the iron as the thiocyanate (3), the chromium as diphenylcarbazide (4), the nickel as dithiooxalate (5), and the molybdenum as

TABLE 4.—AMOUNTS OF METAL TAKEN UP BY COOKING 400 GRAMS OF VARIOUS FOOD MATERIALS FOR ONE HOUR IN CONTACT WITH 4 SQUARE DECIMETERS OF ALLOY

FOOD	ALLOY QB			ALLOY QA				ALLOY A		
	Iron	Chromium	Nickel	Iron	Chromium	Nickel	Molybdenum	Iron	Chromium	Nickel
	mg.	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*
Apple 1	1.80	....	0.12	4.20	....	0.24	0.02	2.30	....	0.24
Apple 2	1.00	0.03	0.12	0.80	0.25	0.12	0.00	0.80	0.30	trace
Chicken	1.40	0.04	0.04	1.10	0.35	0.07	0.007	0.47	0.04	0.02
Gooseberries	1.00	....	0.18	0.90	....	0.02	0.05	1.30	....	0.12
Rice	0.32	0.01	0.01	0.24	0.01	0.02	trace	0.36	0.02	0.02
Rice (stored)	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00
Potatoes	0.76	0.06	0.00	1.60	0.06	0.17	trace?	1.40	0.06	0.06
Flounder	1.90	0.16	0.08	1.90	1.40	0.00	0.00	2.90	....	0.00
Cauliflower	0.86	0.08	0.10	0.52	0.08	0.04	.....	1.40	0.08	0.04
Corn	2.10	....	0.00	2.10	....	0.00	0.00	3.80	....	0.00
Custard	0.03	0.02	0.00	0.01	0.25	0.12	0.00	0.08	0.02	0.00

TABLE 5.—COMPOSITION OF COOKED FOOD, PER KILOGRAM OF MATERIAL

RAW MATERIAL	AMOUNT	SALT	SUGAR	VINEGAR	TIME OF COOKING
	gm.	*gm.*	*gm.*	*c.c.*	*min.*
Apple	440	....	400	...	50
Chicken	240	....	...	...	60
Gooseberries	320	....	428	...	50
Rice	116	13.2	...	...	150
Rice (stored)	236	26.8	...	...	40
Potatoes	200	....	...	...	40
Flounder	200	24.0	...	7.2	15
Cauliflower	200	....	...	...	30
Corn	256	....	...	...	10
Custard	(4 eggs, 800 c.c. milk)		80	...	120[1]

[1] 50°–80°.

thiocyanate (6). The amounts that were taken up by the various foods are summarized in Table 4. In these experiments the food was prepared as in the usual household cooking in triplicate and each metal constituent in the food determined for each alloy. The data given in Table 4 represent

TABLE 6.—FOOD COOKED FOR ONE HOUR DIRECTLY IN METALLIC CONTAINERS OF ALLOY A

(Surface exposed to liquid is 4 sq. dm.)

FOOD	P_H	IRON	CHROMIUM	NICKEL
		mg.	*mg.*	*mg.*
Chicken	...	...	0.05	0.02
Apples (stored 1 hr.)	3.3	0.2	0.01	0.00
Apples (cooking)	3.4	0.3	0.20	0.17
Plums 1	1.7	4.0	0.40	0.08
Plums 2	1.7	...	0.20	0.04
Cottage cheese	...	0.0	0.00	0.00

It is of interest that the acid foods, such as apple and gooseberries, are not necessarily the type which are largely contaminated on contact with the metal. Corn and fish, which are less acid, are more or less uniformly contaminated. Of the three alloys, QB appears to be the best. The average degree of contamination produced by this metal is appreciably less than that of the others.

Comparison of these tests with those made with utensils manufactured from alloy A indicated that the amounts of metal taken up from the cooking utensils were of the same order of magnitude for similar surfaces and lines of contact as shown by the strip tests. The amounts were, if anything, somewhat less, as indicated in Table 7.

Discussion

The results obtained in this investigation indicate that, while certain

TABLE 7.—COMPARISON OF UTENSIL AND STRIP TEST COOKED FOOD

(Both of Alloy A: Fe 74%, Cr 18%, Ni 8%)

	UTENSIL COOKING	STRIP TEST COOKING
Area of metal exposed	4 sq. dm.	4 sq. dm.
Area of metal exposed to vapor	3.8 " "	4 " "
Line of contact (liquid)	45 cm.	45 cm.
Iron dissolved	0.30 mg.	0.80 mg.
Chromium dissolved	0.20 "	0.30 "
Nickel dissolved	0.17 "	slight trace

averages of all the determinations that gave satisfactory checks. Table 5 indicates the amounts of materials that entered into the composition of the cooked food. Similar experiments in which the food was cooked directly in the utensil and then analyzed are shown in Table 6.

nickel-chromium-iron alloys are affected by ordinary cooking operations to the extent that traces of the constituents are determinable by the exceedingly delicate tests that are available, the amounts of metal are so minute that these quantities have no hygienic importance. In the case of

alloy QB (67 per cent. iron, 18 per cent. chromium, and 15 per cent. nickel), the average amounts of metal entering foods of various kinds cooked for one hour were (computed per kilogram of food material):

	Mg.
Iron	2.56
Chromium	0.12
Nickel	0.16

These foods covered the range of acidity between that of gooseberries and that of chicken. In no case could any change be noted in the appearance or taste of food so cooked or cooked and stored for seventy-two hours in a refrigerator in contact with the metal.

These amounts are very small compared with the amounts of metal that dissolve from ordinary cooking utensils in common use. Järvinen (7) recently found that 5 per cent. solution of sodium chloride boiled for three hours in various utensils dissolved the following amounts of metal per kilogram of solution:

	Mg.	*Metal*
Iron pot	104.0	iron
Copper kettle	70.0	copper
Tinned copper kettle	7.0	tin
Nickel kettle	4.0	nickel
Aluminium kettle	9.0	aluminium
Brass kettle	2.0	zinc
	1.2	copper

When sweetened fruit juices were boiled in these utensils, Järvinen found that in many cases ten times the foregoing quantity of metals entered into solution.

A recent investigation by Hunziker, Cordes, and Nissen (8) showed that Allegheny metal (a nickel-chromium-iron alloy) had a high corrosion resistance. Their results, while based upon strip weight changes and not upon analytic findings and for other reasons not strictly comparable with the results obtained in this study, show a marked advantage of this type of alloy. The strip weight experiments of Mrak and Cruess (9), in which various metals including chromium-iron alloys were subjected to the action of fruit juices, show a higher degree of corrosion than was obtained in our experiments with nickel-chromium-iron alloys. The latter type of alloy appears to be peculiarly resistant to corrosion.

The difference between the amounts of metal taken up from nickel-chromium-iron alloys on the one hand and other metals in common use on the other hand indicates that these alloys are hygienically safe for cooking purposes.

Summary

Various nickel-chromium-iron alloys were subjected to an extensive investigation concerning their hygienic fitness for use in contact with food. Determinations were made of the weight changes and the character of film formation that occur in the cooking of various foods of different degrees of acidity in contact with the metal, and of the degree to which traces of the constituent metals enter the food. The results show that the total dissolved metal is exceedingly minimal; iron is the chief metal found while nickel and chromium occur in considerably smaller amounts. For the foods investigated, the contamination at a hydrogen ion concentration of 3 was no greater than at a concentration of 6. An average for various foods cooked for one hour in contact with the 15 per cent. nickel–18 per cent. chromium

alloy showed a contamination of 1.01 mg. of iron, 0.05 mg. of chromium, and 0.06 mg. of nickel for 4 square decimeters of surface in contact with the food.

This investigation was carried on in co-operation with the Bureau of Chemistry and Soils of the United States Department of Agriculture and with the Development and Research Department of the International Nickel Company. It is a pleasure to record the fact of this co-operation and particularly to acknowledge the criticism and interest of Dr. F. C. Blanck and of Mr. R. J. McKay in this connection.

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CHROME PLATING AND ANODIC OXIDATION*

THESE processes have recently been introduced in a considerable number of works and investigation has been made by the Medical Inspectors of Factories with regard to their effect on the health of the workers. These inquiries showed that a considerable proportion of the workers engaged suffer injury to the skin and mucous membranes of the nose from the acid used. The processes and causes of injury and counter measures recommended are briefly described below.

1. Chrome plating is used to give an untarnishable surface to metal articles of various kinds. It consists essentially in suspending the article in a bath or tank containing a solution, the main constituent of which is chromic acid. The metal chromium is deposited electrolytically, the articles being suspended in the solution from the cathode. When the electric current is passed, the evolution of gases throws off the solution from the bath in the form of spray.

Operations in connection with chrome plating include the preliminary wiring-up of articles for suspension in the electrolytic bath, and subsequent swilling, neutralizing, and unwiring. Wiring-up operations are performed on articles that have not been in contact with chrome solutions, but swilling, neutralizing, and unwiring bring the worker into contact with liquids which cause injury to the skin.

2. In the course of the inquiries of the Medical Inspectors, 223 persons engaged in chrome plating were examined. Ninety-five (42.6 per cent.) were found to have dermatitis or circumscribed ulcers or scars of old ulcers. Nasal changes were observed in 116 (52 per cent.), perforation of the septum in thirty-seven, and ulceration or devitalization of the mucous membrane in seventy-nine.

Ulceration of the nasal mucous membrane was seen after only two weeks' employment, and the length of employment of those who showed perforation of the nasal septum varied from six months to four years. These effects are caused by the spray carried into the atmosphere by the evolution of the gases from anodes and cathodes. This risk can only be eliminated by efficient exhaust ventilation.

In all but one of the works visited, some form of mechanical exhaust was found to be applied to the tank. The best method of applying exhaust was found to be by lateral exhaust ducts for removal of gases from both anodes and cathodes just below the edge of the tank and 6 inches to 8 inches from the surface of the solution. From observation it would seem that to insure the effective removal of the spray where lateral ventilation is provided, the distance between the surface of the liquid in the tank and the duct opening should not be less than

* Reprinted from Form 1891, April 29, 1930, Home Office, London.

8 inches. It is essential that the efficiency of the exhaust ventilation should be tested frequently.

Dermatitis or ulceration of the skin is produced by direct contact with the chrome solutions. It affects particularly the skin of the hands, and workers engaged in placing the articles into or removing them from the baths are chiefly affected. Dermatitis and ulceration have also been observed on other parts of the body, in particular the feet, the solution in such cases being splashed from the bath or falling from the articles on removal from the bath, and penetrating the footwear.

Protection of the skin by means of rubber boots and gloves is essential for the prevention of dermatitis among those working at the baths, and aprons are required both for them and for the unwirers. Strict attention by first aid treatment to all skin injuries lessens the liability to ulceration. Protection is also afforded by keeping the skin in a favorable condition by cleanliness and the use of a suitable emollient ointment, which may be applied not only to the skin but also within the nostrils.

In order to insure that the best use is being made of these precautions and to prevent slight cases of dermatitis or of nasal catarrh becoming aggravated, medical supervision is necessary. Such supervision also quickly discloses any diminution in the effectiveness of the exhaust ventilation.

3. The anodic oxidation process is employed for the purpose of preventing erosion of metal. It differs in certain ways from the process of chrome plating, in that the article is oxidized and no chrome is deposited. The percentage of chromic acid in the bath is very much smaller, but examination showed that the same injurious effects are produced on the workers as in the case of chrome plating, and the same precautions are therefore needed.

4. In the case of chrome plating there is also the subsequent process of polishing or finishing by aid of mechanical power. This is subject to the requirements of the Regulations for the Grinding of Metals (Miscellaneous Industries), under which exhaust ventilation is already required. The process is a dirty one, and notwithstanding mechanical exhaust, dust from the green "Compo"—mainly composed of green oxide of chrome and wax—is deposited on the skin and in the nostrils. Washing facilities are therefore desirable, in addition to the exhaust ventilation already required, but no other requirements seem to be necessary in the case of workers engaged in this process.

MICROSCOPIC PHARMACOGNOSY. By *William Mansfield*, A.M., Phar.D., Ph.G., Dean and Professor of Botany and Materia Medica, Union University, Albany College of Pharmacy, Albany, N. Y. Cloth. Pp. x, 211 with illustrations. New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1929.

It is seldom that one finds the details of microscopic structure so well defined as in this manual. The book is largely a series of eighty-eight charts illustrating the structural elements in detail of various drugs and giving a condensed description of each element. The illustrations will appeal to the analyst because of their clear definition. Instead of the smudgy type of photomicrograph that one occasionally finds, the author has been at great pains to make exact drawings, so that with these as a guide and a specimen of the drug before him the student should be able to verify every type of cell and the cell contents with ease. The drawings have been made to scale so that variation in size of any of the cells or cell contents of a given chart or of different charts is an actual variation.

From the point of view of the analyst it would perhaps have been desirable to have stated the approximate dimensions of the structural elements in microns, and to have defined the various cell contents more exactly. When microcrystals are present they are indicated merely as "rosette crystals," "prisms," or "raphides," with no further indication of their crystal form, nor any statement regarding their composition. While not absolutely essential to the identification of the drug, these points are frequently of value.

The author has selected as typical drugs those which fall in the following divisions: leaves and leaflets; leaves and flowering tops; flowering plants and herbs; flowers and flower buds; fruits; seeds; corms; bulbs; tuberous roots; barks; woods; roots; rhizomes; rhizomes and roots; fungi; galls; pith; unofficial drugs. It not only is a useful textbook for the student, but also is an authoritative manual of the subject for the drug analyst.—*L. T. Fairhall.*

THE USE OF THE MICROSCOPE. By *John Belling*, Cytologist, Carnegie Institution of Washington. Cloth. Pp. xi, 315 with index and illustrations. New York and London: McGraw-Hill Book Co., Inc., 1930.

The technic of microscopic observation is not merely a matter of placing an object upon the stage and twisting the lens system up and down. Although all too frequently used with the same expertness one bestows on a field glass, the microscope is capable of much better performance if its principles are rightly understood. The purpose of the present book is clearly indicated by the author in his preface: "For scientific work, it is desirable to get in the microscope the sharpest and most 'contrasty' images possible with the apparatus at hand. There are several dozen adjustments, or varia-

tions of methods, each of which will add slightly to the perfection of the image in the microscope. Alone, each of these slight improvements may not seem worth making; but combined they may cause a decided difference in the brilliancy and crispness of the microscopical image. In this book, the most important of these methods have been brought together from the original papers, and to them have been added the results of the writer's experience gained in years of continuous work with the microscope."

An idea of the scope of the book is perhaps best given by indicating the chapter headings: Use of the Hand Magnifier; Use of the Compound Microscope; The Twin-Objective Binocular; The Monobjective Binocular; The Monocular Microscope; The Routine Microscope; Illumination; Light Filters and Screens; The Condenser; The Object; The Cover-Glass Problem; The Objective; The Water-Immersion Objective; Mirror, Stage, Nosepiece, and Drawtube; The Eyepiece; Microscope Outfits; Drawing; Photography; Testing the Microscope; Care of the Microscope; Rules for High-Power and Routine Microscopy; The Past and Future of the Microscope; Literature of the Microscope; Discoveries with the Microscope; A Hundred Microscopical Objects of Biological Interest; Fixing and Staining Microscopic Objects; Fifty Practical Exercises with the Microscope.

Each chapter is well summarized and a table of practical points is drawn up at the end of each chapter. In addition to a discussion of the theoretical points in the use of the microscope, the author devotes a section to fifty practical experiments in which such important topics as glare, proper use of the various types of condensers, the star test for spherical aberration, cover glass thickness, resolution, measurement, color screens, etc., are treated. These should prove a useful aid to the clear understanding of the instrument. Dr. Belling deserves the thanks of all who are engaged in microscopic work for making available so much pertinent and useful information.—*L. T. Fairhall.*

Sixth International Medical Congress for Industrial Accidents and Occupational Diseases

Geneva, August 1931

The principal questions which are to be discussed are the following:

1. Slow Results and Evolution of Traumatic Wounds of the Spine.
   Reporters: Prof. Dr. Magnus, Bochum; Prof. Dr. Michel, Nancy; Prof. K. Ackermann, Stockholm; Dr. Fauquez, Paris. *Coreporter:* Prof. Dr. Crouzon, Paris.
2. Traumatism of Blood Vessels (Arteritis and Thrombophlebitis).
   Reporters: Prof. Dr. Imbert, Marseilles; Prof. Dr. Diez, Rome; Dr. Danis, Brussels.
3. Cutaneous Affections in Relation to Industrial Accidents.
   Reporters: Prof. Dr. Prosser White, Wigan; Prof. Dr. Koelsch, Munich; Prof. Dr. Oppenheim, Vienna.
4. Previous State and Consequences of Industrial Accidents.
   Reporters: Dr. Pometta, Lucerne: Prof. Dr. Tovo, Turin; Prof. Dr. Liniger, Frankfurt am Main.

Besides these topics, already determined, other questions will be discussed, which will interest industrial medicine more particularly. Details of these questions will appear later.

Moreover, special communications may be made; the subject is left to the author's choice. Persons wishing to make such communications should enter their names by the end of 1930.

An exhibition of radiograms, photographs, and models will be held. All details in regard to this exhibition can be obtained from Dr. Jentzer, Geneva, rue de l'Université 8.

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